HUMANS AND THE WATER CYCLE PROGRAM
Educator Curriculum
Fall 2017

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Program Overview

Program Description (provided to teachers):

How do we impact the water in our communities? Why does it matter? What are we doing to clean it up and what could we do different? In this unit, students will learn how the choices they make on a daily basis impact the water cycle. They'll use an engineering design process to explore the impacts that urban systems have on local waterways and the humans that live near them. Students will work in small teams to research and develop real-world solutions to water quality issues in an urban environment using a community model. They'll explore the state-of-the-art Brightwater treatment plant, carry out investigations in our wastewater lab, and dig deeper into water-use issues in our exhibit hall.

The Humans and the Water Cycle program is designed for classes that are studying human impacts on the water cycle, wastewater, water use, urban infrastructure, and STEM careers. This programs involves a tour of the Brightwater Treatment Plant and is only for students aged 9 and up. Hard hats and vests will be provided for students. Closed-toe shoes are required for this program.

OUTCOMES

Students will leave the program with the capacity to:

- Identify how their learning connects to their personal experiences, prior content knowledge, and community.
- Understand the engineering design process and how it can be applied to urban issues.
- Understand the role that wastewater treatment plays in protecting human health.
- Explain how their personal choices impact both built and natural water systems.

OBJECTIVES

By the end of the program students will have:

- Explored a state-of-the-art wastewater treatment facility
- Engaged in argument about their personal choices as they relate to water
- Applied an engineering design process to urban water problems.
- Explored different water issues and how they connect to human and environmental health
- Discussed the different water issues facing communities around the globe

General Schedule

9:00	Educators Arrive and Set up Lab
10:00	School(s) arrive **Split into Field Groups. Field Group Introductions**
10:05	**Whole Group introduction in the Lab**
10:30	**See below for flow for each field group**
11:45	**Lunch**
12:15	**See below for flow for each field group**
1:30	**Combined field group conclusion**
2:00	**Bus departs – wave goodbye!**
2:00	**Educators Clean Up**
2:30	**Educators Post Program Discussion**
3:00	**Educators Depart**

	Group A	Group B	Group C	Group D
10:05	Shared Introduction		Shared Introduction	
10:30	Treatment Plant	Lab work	Treatment Plant	Lab Work
11:15		Exhibit Hall		Exhibit hall
11:45	Lunch		Lunch	
12:15	Lab work	Treatment plant and conclusion	Lab Work	Treatment plant and conclusion
1:00	Exhibit hall and conclusion		Exhibit hall and conclusion	
1:30	Shared Conclusion		Shared Conclusion	

3.5-hour schedule

- Exhibit hall scavenger hunt is eliminated or shortened

Prep for the Day

Prep for each group:

- Backpack with 1st aid kit & IslandWood Radio
- Laminated journal and clipboard with wet erase marker
- White hard hat, safety vest, and goggles
- Treatment plant radio (1 per room, only need when on treatment plant)
- Key and key card (check out from above the microwave)
- Instructor packet and clipboard with wet erase marker

To write on the white board:

- Learning target on tripod white board: *"We can research and develop solutions to deal with polluted water in a city."*
- **"**Word bank" and box on one margin of the white board.
- **"**Science Practices Use" and box on one margin of the white board.

Classroom Prep (see list of materials)

- Large clipboards, one per student, pencils sharpened
- Set of photos, one per table (one each of historical and modern day photos)
- Using magnets, attach science practice cards to tripod whiteboard
- Field journals attached to clipboards
- Microbiologist Bin x1
    a. Compound microscope x4 (single lens, small scope)
    b. Glass slide with wastewater samples
    c. Omax stereo compound microscope x2
    d. Document camera x1
    e. Laptop x1
- Chemical Engineer Bin x1 with:
    a. Paper towel dispenser with paper towels
- Fatberg Bin x1 with:
    a. Bucket and lid with trash filter holes x1
    b. Shake tubs x3
    c. Bin of trash materials x1
    d. iPad with Nat Geo Fatberg video loaded

Decisions to Make:

- In each classroom, one group will go to the treatment plant before lunch and one will go after.
- Decide who will facilitate classroom instruction

Activities

INTRODUCTION (20-25 minutes)

Learning Target: *"We can research and develop solutions to deal with polluted water in a city."*

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
• Asking questions and **defining problems** • Developing and **using models** • **Obtaining, evaluating**, and communicating information	• **ESS3.C: Human impacts on Earth Systems**	• **Cause and effect** • **Systems and system models**

FIELD GROUPS – 5 minutes

1. Coming off the bus, each class is split into two field groups.
2. Introductions of field group members. Each member of the group shares their name and a way that they've used water today.
3. Today is about understanding **how humans impact the water cycle with the decisions we make as individuals and communities and how all of our choices together as a community can have a huge impact, either positive or negative.** **We'll investigate the history of our area and how people came together determine the causes of, and design solutions to, a big urban problem that had serious effects on many people.**

The two field groups then meet back up in the lab.

IN THE LAB (Introduction of historical scenario and wastewater model) – 5 minutes

1. As one instructor begins the program intro, the other instructor should pull chaperones outside to give quick chaperone orientation. Teachers can stay in the classroom.
2. Instructors pass out 1958 pictures of kids at the beach (Metro campaign poster). Have students discuss the following question at their table:
    - **What information can you gather from this poster?**

3. *This is a picture from the 1958 when 20 million gallons of raw sewage were going into Lake Washington every day.The lake had become so polluted that beaches and fishing were closed and it smelled terrible.*
    - How many of you have ever been swimming in Lake Washington? Fishing in Lake Washington?
    - How many of you have been swimming or fishing in any lake?
4. *Before we do anything else, we need to understand what exactly our community was putting into the lake when we were using water. To understand what we mean by "wastewater", we'll start by brainstorming all of the things that go down drains INSIDE of buildings. In order to do that, we're going to use a **model** to help us visualize what the polluted lake looked like.*
5. Students turn to page 2 of their journals.
6. Start off with a few examples or have students share a couple of examples (soap from when you wash your hands, toothpaste, toilet paper, etc.).
7. At tables, students brainstorm all of the things that go down the toilets, sinks, and other drains inside of schools, homes, and businesses. Page 2 of the journal is organized in columns by drains to help students think of all of the various things that are in wastewater.
8. Pass out a model of a lake (clear plastic bin containing clean water) to each table. This represents a lake with no pollution. Each table should also get the four small sample cups labeled with the four categories.
9. Project the chart showing the 4 categories of substances in the wastewater.
10. Instructor introduces the first category and has one student read the description aloud. Students dump the associated container into the model of the lake.
11. Repeat for all four categories.
12. *All of this stuff mixed together is what we call "wastewater". You may have heard the word sewage before. These words mean the same thing.*
13. Add "wastewater" to word bank on the whiteboard.
14. Pass out modern picture of Lake Washington.
    - What do you notice about this picture?
15. *This is Lake Washington today. Local people were able to identify an urban problem and come up with solutions to help fix the dirty, polluted lake but it's not a perfect solution. We're going to explore how the lake got cleaned by researching what was done and look into some of the problems that still exist today.*
16. Have students read the learning target: ***"We can research and develop solutions to deal with polluted water in a city." We'll look at how all of the dirty water that we create impacts human health and environmental health, and figure out how we can make choices that keep our water clean and our water systems working.***
17. Describe science practices and identify the two that have been used so far; developing and using models (the lake model), and obtaining, evaluating, and communicating information (campaign poster as primary source material).
18. One group leaves to explore the treatment plant while one stays behind for the wastewater lab.

TREATMENT PLANT EXPLORATION (75 minutes)

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
• **Developing and using models** • **Obtaining, evaluating, and communicating information** • **Planning and Carrying out Investigations**	• **ETS1.A: Defining and delimiting engineering problems** • **ETS1.B: Developing possible solutions** • **Human Impacts on Earth Systems Developing Possible Solutions**	• **Systems and system models** • **Structure and Function** Connections to Engineering, Technology, and Applications of Science • **Influence of Science, Engineering, and Technology on Society and the Natural World**

***Learning Target:** "I can determine what types of water pollution the treatment plant can solve and what it cannot."*

A. Treatment Plant Exploration (1.25 hours)

Engineers have designed this place to take care of many different problems associated with wastewater. The purpose of the tour is to visit a number of different places on the plant and figure out how engineers have designed solutions to problems. At each spot, students will record the problem and the solution.

1. Students will explore the treatment plant to **obtain information** about how **engineers developed solutions to remove trash, germs, and organics from the wastewater.**
2. All students will need to wear three pieces of safety equipment in order to enter the treatment plant; safety glasses, a high-visibility vest, and a yellow hard hat.

Teaching on the treatment plant:

- ✓ *Clipboards pencils should be clipped in until you get to the first stop. This will keep them from being a distraction while walking.*
- ✓ ***Make sure you have both your IW radio AND a BW treatment plant radio with you and that they are on and the volume is loud enough so that you can hear.***
- ✓ *Take a moment before you get suited up to check everyone's footwear. If any students or chaperones are going to put on different shoes for the TP tour, now is the time.*

After students have geared up for the treatment plant, gather them up and go over the following safety rules:

Treatment Plant Safety:

1. ***This is the last chance for the next hour or so to use the restroom.***
2. ***Hardhats, vests and safety glasses must be worn the entire time and should be held when looking over tanks.***
3. ***Close-toed shoes are an absolute requirement for the treatment plant, no exceptions.***
4. ***Shoes must be tied and care must be taken when walking; there are tripping hazards.***
5. ***Do not touch any buttons, dials, switches or levers.***
6. ***Feet must stay on the ground at all times; curbs do not count as the ground!***
7. ***The instructor will be the leader of the group, so everyone must stay behind him/her.***
8. ***One chaperone will be at the end of the group to make sure everyone is together.***

9. ***Once the tour starts, students and chaperones will not be able to leave the tour group until the tour is over except for in emergency situations.***
10. ***If your students need to cover their nose due to the smell, they should use their elbow or clothing, not their bare hands.***

Before entering the plant

1. Students turn to page 7 in their field journals.
2. Treatment plants are designed by engineers to solve some (but not all!) of the problems that our wastewater creates. Each stop in the plant is framed as an engineering problem. Students will read the problem and then the instructor will describe the solution Students are responsible for recording the solution in their journal.

Outside the first building

1. About to enter the gallery and travel all of the way to the far end of the plant.
2. Much of the treatment plant is under ground.
3. It might be loud in here—warn them that they might hear a very loud sudden sound, but that it is normal and not to worry.

At the top of the stairs

1. At the top of the stairs, review the four groups of items in the wastewater.
2. **Because it can be very loud at the first stop, ask a student to read the PROBLEM for stop number 1 here: "People flush all kinds of trash that shouldn't go down the drain, clogging pipes and breaking pumps."**

In the gallery

1. Take a moment to check out all the pipes and pumps. Pipes that are labeled with yellow and orange contain air, blue and green contain water, and red is for fire suppression. Arrows tell you which way it's moving.
2. It's loud down here! Pumps sometimes release air pressure and it can be shocking. Move through this area, feel free to take a look around but don't linger too long.

Teaching on the treatment plant:

✓ *When first entering the gallery, open the door slowly and look for forklift or cart traffic.*

(Each of these problems / solutions can be found in the student field notebooks too. Students will fill in the blanks at each stop and participate in a discussion.)

STOP 1: Trash Removal

1. Divide the group into three and pass out the trash bins, asking kids to **investigate what is in them and**

Teaching on the treatment plant:

✓ *Remember the 4 P's: Poop, pee, poop, puke, and toilet paper. These are the only things that should ever go in your toilet (unless you're cleaning it).*

make observations about the different types of trash that end up here at Brightwater.

2. Gather back together. Show trash screen and photos and describe the screen as the engineering solution for removing all of the trash from the water.
3. **Students record the SOLUTION in their journal – Ex: "the trash screen removes anything larger than the holes." Students can draw or describe the screen but if drawing, should also add labels to show how it works.**
4. Introduce the treatment plant "cloudiness" scale. You can introduce the word "turbidity" here but don't rely exclusively on it or expect students to understand what that word means. Don't fret if they don't know turbidity; just use cloudiness and move on.
5. Measure the cloudiness of the sample and record in the box next to Stop 1.
6. In the far-right column, students record what was removed at this stop and cross it off of the list on the left.

STOP 2: Scum Room (*Primary Treatment*)

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1. **Ask a student to read: "PROBLEM: Now that the trash is gone, the water is still full of poop, food, and other organics."**
2. **Pass out the models of the wastewater (**the **containers** with **sand, water, and oil) and ask the groups to shake the containers and then hold them still.**
    - **What do you observe happening to the water as it sits?**
    - **What collects on the top?**
    - **What collects on the bottom?**
    - **Where is the cleanest water?**
3. *This is a combination of **gravity and density** acting on the material in the wastewater.*
4. Show students the diagram that details the scum removal process. The same three layers should be observable on the diagram and in the models.

> **Teaching on the treatment plant:**
>
> ✓ *Remind students before entering the scum room to keep a hand on their hard hat and glasses when looking into the tanks. NOTHING should ever be dropped into the tanks.*
>
> ✓ *The small jar of biosolids should never be opened; students may smell and touch the larger jars (GROCO) that are mostly sawdust.*

5. **Explain the SOLUTION: Engineers let the water sit still, the heavy materials sink and the lighter materials float to the surface. These materials are scraped off and sent to be processed into biosolids.**
6. **Students should draw and describe the engineering solution.**
7. **A couple of things for students to look for in scum rooms: blue trough where the cleaner water is leaving the building, black spinners that scrape the scum off the top, scum floating on top of water.**
8. Walk your group through the scum room.
9. **Measure the cloudiness of the sample and record in the box next to Stop 2.**
10. Ask your students what they think happens to the organic solids that are removed.
11. In the far-right column, students record what was removed at this stop and cross it off of the list on the left.

12. Share the biosolids samples, students may touch and smell the Groco samples (the one that is mostly sawdust) but not the single small jar sample.

STOP 3: Microbe Hot Tub (*Aeration*)

1. **Ask a student to read: "PROBLEM: There are BILLIONS of tiny bacteria still in the water, including some that are harmful to humans and wildlife."**
2. At this stage about 50-60% of the solids have been removed. The remaining solids are being consumed by the bacteria that are in turn being consumed by the microbes.
3. **Show students the pictures of the microbes. If they've already done the lab, they should look familiar. If not, explain that you'll be examining a sample back in the lab when you return.**
4. Put on gloves from the storage cabinet first. Open the dirty gloves box now so that you can drop the dirty gloves straight into it when you're done.
5. Open hatch and pull out some foam using the bucket on a wire. This is gas produced by the microbes as they are digesting the waste in the water.
6. **Explain the SOLUTION: We send the waste water into the Microbe Hot Tub so that the microbes can consume the bacteria who are consuming the remaining organics.**
7. **Students should draw and describe the engineering solution.**
8. **Remove the sample from the cabinet and measure the cloudiness using the chart. Record this result in the box next to Stop 3.**
   - Why is it MORE cloudy here? (*The wastewater is concentrated here and full of clumps of organics, bacteria, and larger microbes*)

Teaching on the treatment plant:

- ✓ *If you notice we are low on gloves in the storage bin, please let the coordinator know as soon as you return.*
- ✓ *If you are the last group, please remember to bring back the bucket on a wire.*
- ✓ *Make sure students are standing back from the hatch when you pull out the bucket. Be careful if it's windy! The foam can fly off of the bucket.*

STOP 4: Back to the Water Cycle

1. Ask a student to read: **"PROBLEM:** All of those little bacteria-eating creatures (microbes!) are still in the water and some could cause health problems in the environment. **"**
2. Show students the filter model with the holes in it. This is a model of the membrane filters. Each "straw" has millions of tiny holes in it.
3. Explain the **SOLUTION:** Engineers designed tiny straw filters to get the remaining organics and bacterial out.
4. **Remove one of the models of the membrane filters, the container of beans, and one of the stuffed microbes. The beans represent different chemical and water molecules and are able to pass right through the pores while the microbes and any remaining organics stick to the outside.**
5. Students should draw and describe the **engineering solution**.

6. Compare the samples from each stop to show the progression of the water through the process. **Remove the final sample from the cabinet and measure the cloudiness using the chart. Record this result in the box next to Stop**
    - What is still in here that we can't see?
    - Which category didn't we talk about yet?
7. Return all materials to the storage cabinet and take your group across the road and up the stairs to the observation deck on the roof of the disinfection building. This is where the water leaves Brightwater and travels 13 miles to the Puget Sound.

Teaching on the treatment plant:

- ✓ *Please make sure that the contents of the storage bin are replaced neatly when you are done with the materials.*
- ✓ *The pores in the membranes are 6 microns across; students will think they can see them, but they would need a high-powered microscope to do so!*
- ✓ *The interpretative sign can be a big distraction here, so move your group down away from it when addressing them.*
- ✓ *Remind students before climbing the stairs to keep a hand on their hard hat and glasses when looking into the tanks. NOTHING should ever be dropped into the tanks.*

WASTEWATER LAB (45 minutes) Pages 4-6

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
• Planning and carrying out investigations • Engaging in argument from evidence • Analyzing and interpreting data	• ESS3.C: Human impacts on Earth Systems	• Cause and effect •

Learning Target: *"We can develop solutions to deal with polluted water in a city."*

Water lab tips:

- ✓ *If possible, place one adult at each lab station to remain there for each rotation.*
- ✓ *Ideally, you should be stationed at the Microbiology station to assist with microscopes and slides.*
- ✓ *Slides can dry out rather quickly, so you may have to redo them during your lab.*
- ✓ *Microscopes should be set to the 10x lens (that's 100x magnification). Students should not change the lens.*
- ✓ *The lipstick can be a bit messy, students should be reminded to press lightly when drawing with lipstick on the whiteboards so that we can make it last.*

1. Have students take a seat in the center of the room.
2. Remind students of the learning target for the day and how the lab activities connect to it.
   a. *We're going to work together here in the lab to help us understand some more about the pollution problems that wastewater can cause so we can figure out the choices we can make to help solve them.*
3. Walk to each station and give a brief overview of each of the three stations so that students are familiar with what they will be doing.
   a. At each station, read the investigative question aloud to the group.
4. Make it clear that each lab station has a set of directions that students are to follow closely as a group. Each station has its own page in the journal. Students are responsible for completing their journals.
5. Split students into 3 equal groups and have one adult at each station. Release groups to their station and begin timing the first rotation.
6. Each station is designed to take approximately 15 minutes. If students are finishing earlier or are lagging behind, you may need to hurry them along or adjust the timing.
7. For each station description below, there is a question to connect the station to the learning target for the day. These can be used to debrief the lab or as a probing question when circulating between groups.
8. After the students have completed all three stations, bring them back to the tables at the front of the room.
9. Revisit science practices and identify which practices were used at the lab stations.
10. Depending on time, your debrief can take several forms:
   a. Pick one of the connective learning target questions below, have groups discuss at their table and share out.

   b. Have students **argue from evidence** about which cleaner they would choose for their school and why.
   c. Have students share something that surprised them or that they found interesting during the lab.

11. Remind students that they'll be using this information they've obtained to help them develop solutions in their community models at the end of the day.

Lab Station Details:

1. **Chemical Cleaner Station** - ***How do we choose the chemicals we put down the drain and why?***
   a. **Students will plan and/or carry out an investigation to test three different cleaners**, a "natural, biodegradable" cleaner, a standard chemical cleaner, and a homemade cleaner. Writing with lipstick on a whiteboard, they'll follow a (or if students are in middle school, develop their own) simple procedure to **test the efficacy of these cleaners by analyzing their data and engaging in argument** about which type of cleaner is right for their school.

   Connective Learning Target Question: *How can you encourage members of your community to make informed choices with the chemicals they use?*

2. **Microbiology** – ***What impact do the germs in the water have on human health?***
   a. Students will examine a sample of activated sludge (from the microbe hot tub) using the compound microscopes. They are looking for and identifying microbes that are helping to clean the water, consume bacteria, and decompose remaining organic materials. **Some of these microbes and the bacteria that they consuming are harmful to human health if they get into the environment and can cause diseases in both people and animals.**

   Connective Learning Target Question: *If not removed, what impact would these microbes (including bacteria) have on your community?*

3. **Fatbergs!** – ***How does the trash we flush impact the system?***
   a. *A fatberg is a giant wad of greases, fats, paper towels, wipes, and other trash that can clog up entire sewer systems.* Students will examine what happens to different substances when they're flushed down the drain. Each group will begin by shaking water and toilet paper and then pouring it through a model of a trash filter and recording their observations. They will then repeat this process with two other substances from a number of choices (paper towels, tissue, and/or wipes). Students are asked to analyze the impacts of trash that doesn't break down, especially when it combines with fats and grease to create clogs.

   Connective Learning Target Question: *What is something you could do in your community to reduce the amount of grease, fat, oil, and other trash in the system?*

EXHIBIT HALL EXPLORATION (30 minutes)

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
• Obtaining, evaluating, and communicating information	• ESS3.C: Human impacts on Earth Systems	•

Learning Target: *"We can develop solutions to deal with polluted water in a city."*

The exhibit hall scavenger hunt is mostly self-guided by the students. They will work on page 6 in their journal to complete a series of questions relating to global and local water systems and water use.

Exhibit Hall tips:

- ✓ *Keep in mind that other groups may be having a quiet discussion in here when considering how you release your students once inside.*
- ✓ *It's helpful to make it clear to students that the video screen is off limits during the scavenger hunt.*
- ✓ *Groups need to stay in the exhibit hall during the scavenger hunt.*
- ✓ *Please be respectful of the fact that there may be rental groups using the building.*
- ✓ *This activity can be cut short if you are running behind on time.*

1. Have students turn to page 6 in their journal.
    a. The goal of the exhibit hall scavenger hunt is to introduce students to some of the water challenges that the global community faces and the broader water systems that they are a part of.
2. Gather students before entering the building and introduce the scavenger hunt. Students can work alone or in a team. There are hints within the question for some of the more difficult things to find.
3. Give students 10-15 minutes to explore the exhibit hall and complete the scavenger hunt. Walk around and gauge how much time they'll need.
4. Once students have completed the scavenger hunt, gather them into the center of the room again. Have students sit on the floor in a circle.
    - What is something new that you learned in the exhibit hall?
    - What is something that surprised you?
    - Did you learn anything that could help you **develop solutions** to water pollution in your community?
5. If you have extra time after your discussion, feel free to watch the "Circulator" video (about 8 minutes) in the foyer area.
    a. *"Blashfield calls Circulator "...a poetic interpretation of the water cycle," helping visitors to understand and care about the science of the Brightwater treatment technology and its environmental benefits. Water takes myriad forms and interacts with objects throughout the piece, which plays out over seven media screens—five rectangular screens on the wall, one circular screen below them, and one circular screen embedded in the floor at the visitor's feet."*
6. Make sure to do a quick visual sweep of the room before you're done and leave the room in the same condition it was in when you arrived.

DEVELOPING SOLUTIONS TO URBAN PROBLEMS (30 minutes)

Learning target, *"We can research and develop solutions to deal with polluted water in a city."*

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
• **Developing and using models** • **Constructing Explanations and designing solutions** • **Obtaining, evaluating, and communicating information**	• **ESS3.C: Human impacts on Earth systems** • **ETS1.B: Developing possible solutions** • **ETS1.C: Optimizing the design solution**	• **Cause and effect**

1. Both field groups return to the lab with 30 minutes remaining in the day for a shared debrief.
2. Revisit the learning target for the day: *"We can research and develop solutions to deal with polluted water in a city."*
3. *We've looked at one of the really big solutions to water pollution, the wastewater treatment plant. In this region, engineers designed big treatment plants like Brightwater to help clean up Lake Washington. Based on our research today, we know that there are limits to the treatment plant as a solution for polluted water. It's not perfect. There are things it cannot remove from the water and other things that people do that can keep the system from working.*
    a. *What was an example of something that the treatment plant couldn't remove from the water? This is a limitation of the treatment plant as a solution.*
    b. *What did we look at that could keep the treatment plant or wastewater system from working correctly? (fatbergs, trash, wipes, etc.)*
4. **At each table, groups will get a map or MODEL of a community around a lake. We're going to use this model to think about all of the other sources of pollution in an urban area that can pollute a lake. The treatment plant can only remove pollution from wastewater, the water from inside of buildings. If we want clean water in our community, we have to also have solutions for the water that we pollute that is *outside* of buildings.**
5. At each table, groups draw arrows showing where pollution is coming from and where it ends up. Students should label the types of pollution and also draw in any sources they can think of that aren't included on their community model.
    a. Project a model and show an example of what you're asking students to do.
6. Students share examples of pollution that their group identified.
    a. How does this pollution affect your community?
7. *Based on everything we've learned today, your job as a group is to think of ways that we can solve some of the pollution problems in your community. When communities come up with*

Some examples of possible constraints for urban solutions:

- ✓ **Realistic** – needs to be something that could actually work in the real world
- ✓ **Time** – can't take too long to complete
- ✓ **Disturbances** – has to minimize disturbance to people's lives
- ✓ **Cost** – $$$ (also; who will pay for it?)
- ✓ **Locally-based** - Solutions can't just move pollution to someone else's community

*solutions to problems, there are limits to what they can do. We call these **constraints**. These are things like money and time that we have to consider when thinking of a solution.*

8. Write constraints in the word bank on the board. There are three basic constraints that must be considered in any solution; time, money (including who will pay for it), whether it is something that can actually be done (needs to be realistic), and finally it needs to help keep pollution from going into the lake.

   a. Other constraints can be considered. Older students may be able to brainstorm some of these.

> **Designing solutions:**
>
> The solutions designed here should not necessarily be engineering solutions. You may need to encourage students to think of social solutions like education programs or informational posters.

9. Groups are given 5-10 minutes (depending on time) to work together to develop solutions. Students can use the back of their community model to write solution ideas down if needed.

10. **Each group shares out the solutions they've developed for their community.**

   a. ***Does your solution follow the constraints we've listed?***

   b. ***Are any of these solutions things that you could do in your neighborhood? At your school? At your home?***

   c. ***What other research would you need to do to test and optimize your solution(s)?***

11. Thank parents, students, and chaperones.

12. Students load the bus and go home!

Appendix I: General Background Information

Detailed Treatment Process Description

Brightwater is the third and newest wastewater treatment plant serving King County. It services residential, commercial and industrial areas of North King County and Snohomish County. Brightwater has the capacity to treat 36 million gallons of wastewater per day. Water leaving Brightwater is 99.9% cleaner than when it entered the facility. Brightwater is designed to treat three types of waste: the water itself, the solids removed from the water, and the air that surrounds these processes.

Treating the Water
Water entering the treatment facility is called *influent*. It contains trash, grit, organic solids (food from garbage disposals, fecal matter, etc.), microorganisms, and chemicals. These contaminants are removed in order of largest to smallest, heaviest to lightest. The water takes about 12 hours to go through the entire treatment process. Once the water is treated it is called *effluent* and is used as reclaimed water at industrial and commercial sites, including the grounds at Brightwater. Surplus effluent is transported to the Puget Sound through the Brightwater Tunnel, which empties into the sound at Point Wells, WA.

Trash Removal: Things such as 'flushable' wipes, paper towels, band-aids, hair, and floss are often inappropriately flushed and enter the wastewater. Trash is problematic in the wastewater system because it does not break down in the sewer pipes and can cause clogs in pipes or damage pumps and cause overflows to streets or lakes. Trash is removed by perforated steel plates that act as filters. This trash is then loaded into trucks and hauled to a landfill in Eastern Oregon. Brightwater produces about a truckload of trash per week.

Grit Removal: Dirt and grit enter wastewater through cracks in the sewer pipes. Grit is problematic in the treatment plant because it can damage the machinery. Wastewater is aerated to help grit settle to the bottom where it is removed and hauled to the landfill. This process is similar to a hot tub: air and turbulence keep organic waste suspended in the water and gravity causes the heaviest particles (rocks, dirt, sand, etc.) to fall to the bottom.

Primary Treatment: Primary treatment is the process during which most of the suspended solids settle out of the wastewater. Gravity causes the larger, denser, solids to settle to the bottom while the lighter greases and oils float to the top, leaving the cleanest water in the middle. Scum skimmers scrape off the top layer of grease and oil while scrapers remove the solids that have settled to the bottom. These materials are sent to the beginning of the solids treatment process, in which the organic material is converted into methane and fertilizer. (Please review 'Treating the Solids' section in this document.) After the water goes through primary treatment, 60% of the solids have been removed. Up until the 1950s, this is all that was done to treat most wastewater. This caused problems in our aquatic ecosystems because the wastewater was discharged into nearby Lake Washington and Puget Sound. When wastewater is discharged into the surrounding waterways, it overloads them with organic material and nutrients. These nutrients act like fertilizer and cause algae and other aquatic microorganisms to grow very rapidly. When those organisms complete their life cycle and die, the natural process of decomposition begins. Decomposition requires oxygen, and because there is so much organic material decomposing, all of the oxygen in the water gets used up. As a result, many of the living things in the water do not have enough oxygen to survive, and the lake experiences a population crash. Once this has occurred, it is very difficult to restore the balance to the aquatic ecosystem.

Secondary Treatment: Secondary treatment is the process where soluble substances and fine particles not already removed at primary treatment are removed. This is a two-step process. First, the wastewater is aerated with warm air, which encourages aerobic bacteria growth. The bacteria-rich water is called 'activated sludge.' The bacteria, which naturally exist in freshwater systems, are given an optimal environment for growth. They eat and metabolize the soluble organic material back down into its basic components: nitrogen compounds, carbon dioxide and water, and cause the fine particles of insoluble material to clump. No solids are removed in the aeration process. The aeration process mimics the same decomposition process that is occurring in natural systems, but it is accelerated and magnified by the introduction of massive amounts of oxygen. In the natural world, the rate of decomposition is limited by the amount of oxygen in the water, and ultimately the amount of waste in the water exceeds the amount of oxygen available to help break it down, creating an imbalance in the system. In addition to decomposition, the bacteria also help the remaining fine particles clump together, making them easier to filter out in the next step of secondary treatment: filtration by membrane bioreactors.

Once the activated water leaves the aeration tank, it enters the membrane bioreactor, which consists of thousands of tiny filters. Membrane filters are flexible straws with microscopic holes in their sides called 'pores.' The pores are large enough to allow water molecules and viruses through, but are too small for most bacteria to fit through. Suction is applied to the end of each filter, sucking the clean water into the middle and leaving the bacteria and solid particles on the outside. These solids are sent to the beginning of the solids treatment process to be converted into methane and fertilizer in an anaerobic digestion tank (Please review 'Treating the Solids' section in this document.). Once the water has gone through secondary treatment, 99.9% of the solids have been removed.

Disinfection: The final step of the water treatment is to kill enough of the remaining pathogens in the effluent to comply with water quality discharge permits. Sodium hypochlorite, a chemical similar to bleach, is used to disinfect the water. Effluent is highly regulated and tested on a regular basis. Fecal coliforms are monitored and used as an indicator to signal the possible presence of other bacteria and pathogens in the effluent.

Treating the Solids

Organic solids are removed from waste water during primary and secondary treatment. These solids are mixed with polymer, an additive that helps the solids clump together and congeal, then sent down a gravity belt thickener which uses a thin mesh to strain out the water and compact the solids. The thickened solids are then sent to the digester. The digester is a large tank that is heated to 98° F. Bacteria in the digester use anaerobic (without oxygen) processes to break down pathogens and organic material. This same anaerobic decomposition process happens in the natural world at the bottoms of lakes where oxygen is in short supply. At Brightwater, the process is accelerated by adding heat to the system, allowing the bacteria to remain active. During this process methane gas is released. At Brightwater, this gas is combusted to produce heat for the digester and other buildings on site. Solids are constantly being added and removed, but on average they remain in the digester for 30 days.

Once the solids leave the digester, they are sent through a centrifuge which removes most of the remaining water. Polymer is added once again to help thicken and congeal the solids. The final product is called biosolids, or cake. Biosolids are rich in nutrients that plants need to grow. Some of the biosolids are loaded into a truck and sent to eastern Washington to be used in agriculture as fertilizer by farmers, some are applied to tree farms or restoration projects in western Washington, and the rest is turned into a compost product called GroCo that can be used for home landscapes and gardens.

Treating the Air

Brightwater has invested in advanced odor control technology that keeps foul air smells from leaving the property. Air from all stages of the treatment process is suctioned off to a three-step odor control process. First the air is cleaned by biological scrubbers that contains activated bacteria which break down sulfides (the particles in the air that give it a foul smell). Next the air is forced through a chemical scrubber which uses sodium hydroxide and hypochlorite to help remove smelly particles. The final step is a carbon polisher which leaves the air with virtually no odor. Like all parts of the treatment process, the air emission is also monitored and regulated.

Nitrogen Cycling in Wastewater

About 80% of the nitrogen that leaves the human body is in the form of urea. Urea is produced exclusively in the liver. In wastewater, urea reacts with an enzyme called urease that is produced by certain species of bacteria present in the water. This reaction produces carbamic acid that quickly decomposes to form ammonia (NH3) and carbon dioxide (CO2).

Now we have to begin to worry about the nitrogen in the water since excess nitrogen is essentially fertilizer and fertilizing the Puget Sound is a terrible idea. Basically, we want to create ideal conditions for the nitrogen cycle to function so that the N in our ammonia can reenter the air as inert and harmless nitrogen gas (N2).

Step-by-step:

1. Ammonia + bacteria + oxygen = nitrite
2. Nitrite + oxygen + bacteria = nitrate (note that these two steps require oxygen)
3. Nitrate + organics in the wastewater + bacteria = nitrogen gas + oxygen
    a. In this final step, the water passes into an anoxic zone, or an area of the plant with no oxygen. This forces the bacteria to use the oxygen in the Nitrate (NO3), releasing the nitrogen as a gas.

Some additional resources:

http://en.wikipedia.org/wiki/Sewage_treatment#Nitrogen_removal

http://themedicalbiochemistrypage.org/nitrogen-metabolism.php (see the section on the Urea Cycle)

http://en.wikipedia.org/wiki/Ammonia_volatilization_from_urea

http://en.wikipedia.org/wiki/Nitrogen_cycle

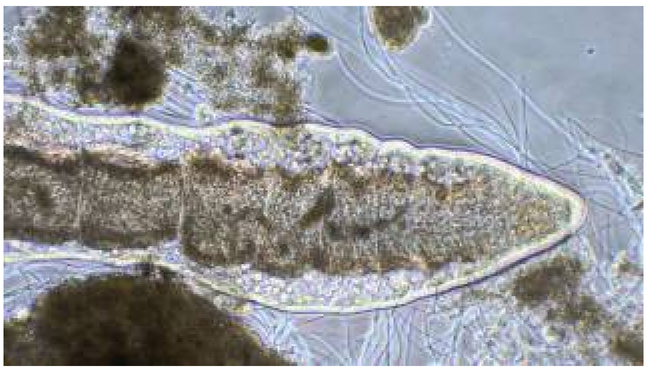
http://water.me.vccs.edu/courses/ENV211/lesson21_print.htm

Wastewater Microbiology (Sludge Bugs)

PROCESS ANALYSTS (what we call microbiologists) monitor the species present to determine how to manage the system. The bacteria are doing most of the work of breaking down the actual organic matter, process analysts use the bigger stuff as indicators for the health of the bacterial population. Here are some things they are looking for:

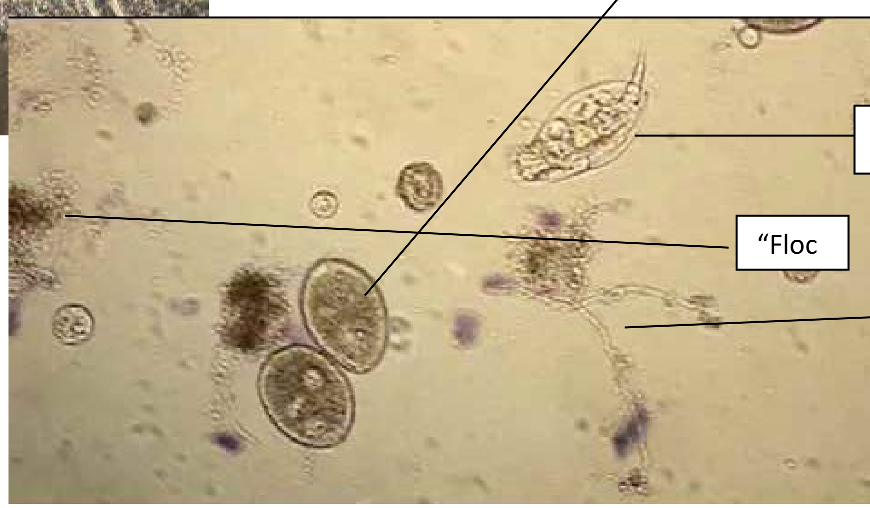
- Lots of worms = older, healthier sludge
- No higher life forms = possible toxic contamination or lack of oxygen
- Sudden increase in amoebas = sudden increase in oxygen
- Lots of rotifers = older, healthier sludge
- Ciliates = healthy system

Bristle Worms



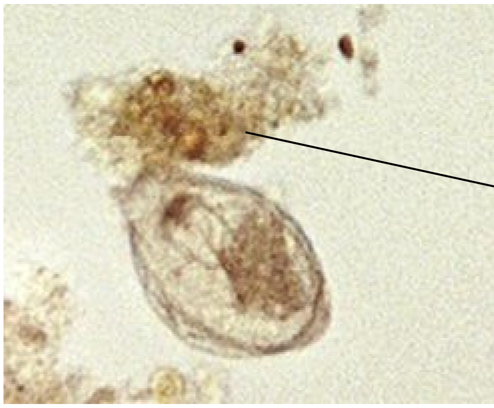
Nematodes

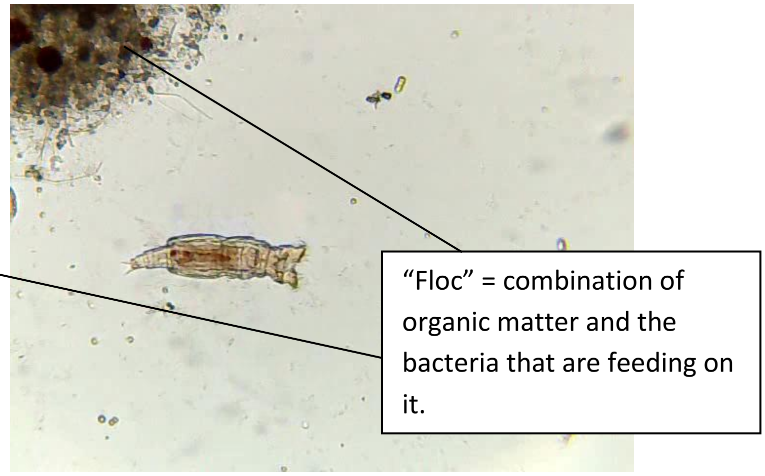
Much larger than other microbes



Ciliates (can swim and chase their prey – mostly we see free-swimming ciliates)

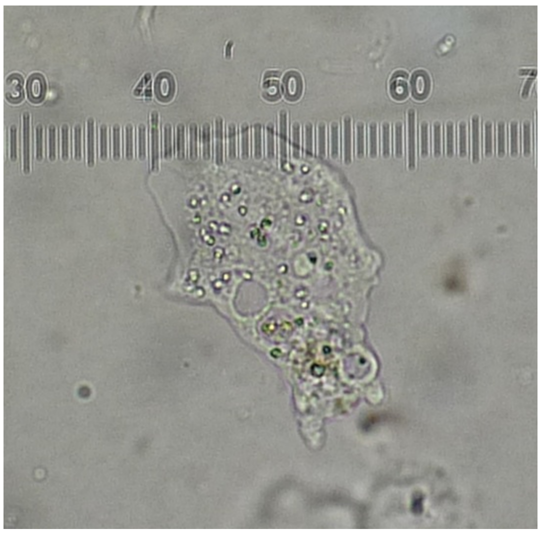
Rotifers

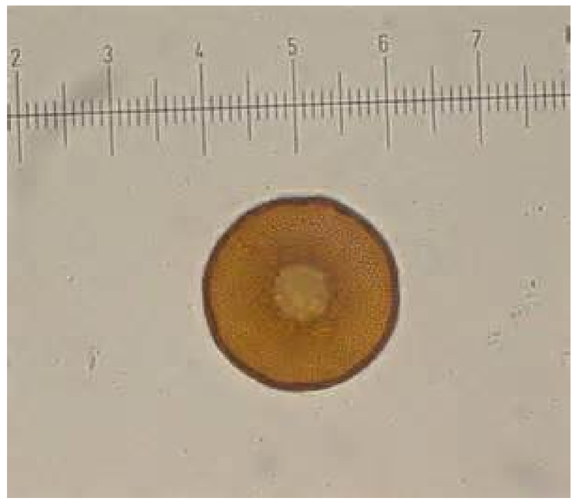




Amoeba (VERY rarely seen @ BW)

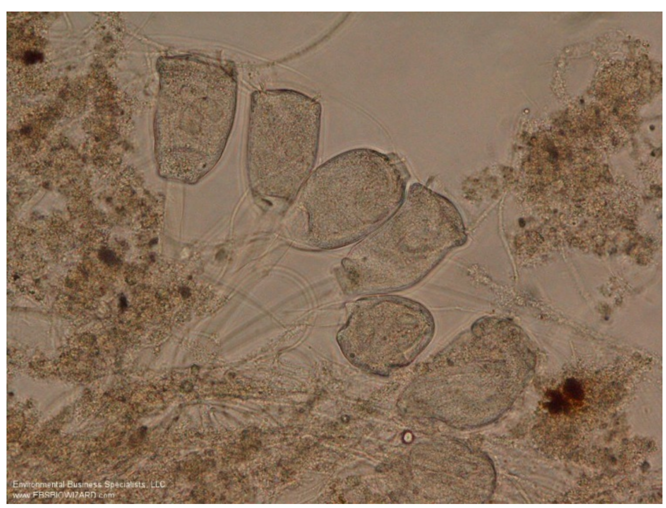
Shelled Amoeba (Arcella)





Flagellates (much smaller, little swimmy things)

Stalked Ciliates



Appendix II: Next Generation Science Standards

The Next Generation Science Standards (NGSS) are made up of Performance Expectations that incorporate three dimensions: the **science and engineering practices**, **disciplinary core ideas**, and **crosscutting concepts.** For more in depth information on the NGSS, visit the Equip or NSTA websites.

All three dimensions are used during the course of this program. To help educators recognize where we are using them, the relevant dimensions are listed at the beginning of each lesson. In addition, the dimensions are color coded when they show up in the text of the lesson. To keep it simple, full descriptions are not provided during the lesson, but below you can find specifics for each category including where it is used. We do not list all the parts of each dimension; just the specific grade 3-5 and/or 6-8 bullets relevant to this lesson.

The program also supports specific NGSS performance standards. These can be found listed at the end of this section.

Science and Engineering Practices

There are eight key "practices" that are essential to the work of scientists and engineers. They are not used in any specific sequence, being applied as needed to build understanding (science) or solve problems (engineering). By reinforcing these practices and making our use of them explicit during this program we help students see that THEY can be scientists and that practices can be applied towards building understanding the real world.

Science and Engineering Practices Only the bullets for each practice that are relevant to this program are shown	**Where it is used in our program?**
Asking Questions and Defining Problems • Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost. • Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.	• The day begins with the defining of a problem related to urban water pollution in a lake. • While we're not developing investigable questions as part of this program, students may develop their own questions that could be investigated further back at school.
Developing and Using Models • Develop and/or use models to describe and/or predict phenomena. • Develop a diagram or simple physical prototype to convey a proposed object, tool, or process. • Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.	• Models are used to describe systems on the treatment plant. Specifically, the membrane filter (stop 4) and the primary treatment process (stop 2). A trash screen model is used during the Fatbergs! Lab station to observe how the trash screen in the treatment plant removes different types of trash. • A community model (diagram) is used to help understand the urban water pollution problems that are being addressed. • Inputs and outputs are identified on the community model.
Planning and Carrying Out Investigations • Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.	• In the wastewater lab, students carry out (or plan and carry out) an investigation of different chemical cleaners and also carry out an investigation of what happens to different types of trash in wastewater.
Constructing Explanations and Designing Solutions • Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation.	• Students explain the impact that fatbergs have on their community and the impact that certain microbes have on human health.

• Apply scientific ideas to solve design problems. • Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.	• Students apply their understanding of what the treatment plant can and can't do as they think about what problems they need to solve. • Students design multiple solutions to a number of urban water quality issues using their community models.
Engaging in Argument from Evidence • Respectfully provide and receive critiques from peers about a proposed procedure, explanation, or model by citing relevant evidence and posing specific questions.	• While deciding on possible solutions, students argue within their groups about which solutions will meet the criteria for success and decide on a solution or solutions that will work for their community. Students argue which chemical cleaner they would choose to use in their school using evidence from their investigation of each cleaner's efficacy.
Analyzing and Interpreting Data • Represent data in tables and/or various graphical displays (bar graphs, pictographs, and/or pie charts) to reveal patterns that indicate relationships. • Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation.	• Data is analyzed and interpreted during the wastewater lab at the chemical cleaner and fatberg stations. • Graphical displays are analyzed in the exhibit hall.
Obtaining, Evaluating, and Communicating Information [6-8] Integrate qualitative and/or quantitative scientific and/or technical information in written text with that contained in media and visual displays to clarify claims and findings.	• Information is gathered by looking at current and historical documents (the 1958 Metro campaign poster and the current photo of Lake Washington. • Information is obtained and evaluated during the exhibit hall scavenger hunt from various visual displays. • The National Geographic Fatberg video during the lab station is an example of information gathered from video media. • Students communicate information to each other during lab debrief, exhibit hall debrief, and discussions of community models and designed solutions.

Crosscutting Concepts

"Crosscutting concepts have value because they provide students with connections and intellectual tools that are related across the differing areas of disciplinary content and can enrich their application of practices and their understanding of core ideas." — Framework p. 233

Crosscutting Concepts	Where it is used in our program?
Structure and Function • [3-5] Substructures have shapes and parts that serve functions. • [6-8] Complex and Microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural structures/systems can be analyzed to determine how they function.	• Students examine and interact with models of different structures from the treatment plant to understand how they function. • Students examine and illustrate the structure of microbial life that is in the wastewater.

Systems and System Models • [6-8] Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems. • [3-5] A system can be described in terms of its components and their interactions. • [6-8] Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. [3-5] A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot.	• At the end of the program, students use a diagrammatic model of an urban system to describe the different interactions within water systems, including inputs, outputs, and outcomes. • Sub-systems of the treatment plant are explored and described. • The treatment plant is put into context of the larger treatment system and the functions it serves.
Cause and Effect Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering. • [3-5] Cause and effect relationships are routinely identified, tested, and used to explain change.	• Students examine causal relationships between the historical water quality issues in Lake Washington and human water use.
Connections to Engineering, Technology, and Applications of Science ***Influence of Science, Engineering, and Technology on Society and the Natural World*** • The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. • All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.	• Technologies within the treatment system are examined as well as the limitations of the entire system in its ability to address urban water pollution. The economic realities of wastewater treatment are discussed and compared to the state of sanitation systems in other countries (in the exhibit hall). • The consequences of human water use in an urban system are a central topic to the program. Impacts of human actions on water systems as well as positive and negative impacts and their effect on the health of people and the environment are also central.

Disciplinary Core Ideas

This program benefits from knowledge the students come to the program with, but does not spend as much teaching the knowledge as it does applying it. The examples in bold are the material we actually teach.

Disciplinary Core Ideas	Where are these ideas used in our program?
ESS2.C The Roles of Water in the Earth's Surface Processes • [6-8] Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land. (MS-ESS2-4).	• The water cycle is the larger context that wastewater and stormwater systems are a part of.
ESS3.C Human impacts on Earth systems: Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments. (5-ESS3-1) • [3-5] Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments. • [6-8] Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.	• Pollution of wastewater and stormwater is from human activities and cleaning them up are something we do to help protect water as a resource. • The idea that increased consumption has negative impacts is explored in the exhibit hall scavenger hunt and is a part of why we have the treatment plant at Brightwater.
Engineering Design Process: ***ETS1.A: Defining and Delimiting Engineering Problems*** • [3-5] Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (3-5-ETS1-1) [Treatment plant, chemical engineer lab portion] • [6-8] The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. (MS-ETS1-1) [Treatment plant]	• Criteria and constraints on possible additional solutions (beyond the wastewater treatment plant) are defined in the final activity of the day. • Students understanding of wastewater treatment help them define the criteria for what else needs to be solved.
ETS1.B: Developing Possible Solutions • There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. • Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.	• Their criteria and constraints are important in helping students consider which possible solutions they would propose (at the end of the program) • Students can combine various solutions that students come up with to meet multiple needs.

NGSS Performance Expectations

The following Next Generation Science Standards are supported by this lesson. This lesson reinforces the material in these standards but does not replace the need for them to be learned and practiced more deeply in a larger curriculum.

Supported Performance Expectation	How it is supported
3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost. **MS-ETS1-1**. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.	Students have an opportunity at the end of the program to define the problems that are not solved by the Brightwater Treatment Plant.
3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem. ***MS-ETS1-2.*** *Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.*	Students have an opportunity to consider various ideas for solutions in the context of their criteria and constraints. *A systematic process to consider criteria and constraints is not taught during the lesson but students could use one if they have previous learned it.*
5-ESS3-1. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.	Treatment plants are a solution used by many different communities trying to clean up their wastewater.
MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.	Students do no construct this specific argument, but wastewater problems are a direct result of increases in human population and per-capita consumption of water.